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No. 823.

CAN BUILDINGS BE MADE FIRE-PROOF?

By CORYDON T. PURDY, M. Am. Soc. C. E.

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WITH DISCUSSION.

One of the most destructive fires of this year occurred in Pittsburg on the morning of May 3d, the total loss being about \$2 500 000. Three buildings, which were generally regarded as fire-proof structures, and were supposed to be constructed according to the most modern methods, were partially burned, and the contents of two of them were entirely destroyed. This circumstance has aroused an unusual interest among all those engaged in the construction of such buildings. Very much has been written by the technical press, both of the fire and of the lessons which the writers would draw from it. The loss in these particular buildings has also tended strongly to condemn all buildings of their class in the public mind, so that even among men who know most about building construction the question whether buildings can really be built fire-proof or not is pertinent.

The purpose of this paper is to relate in brief the incident of the fire, to describe the important characteristics of the construction, and

to point out the lessons which are taught. Much has already been well said, while some things have been written that are not true, and some important points are not yet brought out. It is hoped that this paper and its discussion by the Society will correct any wrong impressions of the fire, and bring out clearly every point which can be of advantage to engineers or architects.

The author has endeavored to avail himself of every opportunity to obtain definite and reliable information as to the construction of the buildings and the circumstances of the fire, making for the purpose a personal examination of the ruins.

It is one of a very few fires which have burned fiercely in buildings of modern construction, and, while it is not as good a test of some conditions as other fires have been, notably so, the burning of the Athletic Club Building in Chicago, it is of greater interest, because it concerns different methods of construction and several forms of fire-proofing materials. Practically everything that was combustible in the Horne Store Building was burned, and the steel frame on one side was badly wrecked. The contents of the Horne Office Building were also consumed, as was most of the woodwork in the construction of the building. The fire in the Methodist Building was mostly confined to the three upper floors, where the contents and much of the wood finish were burned. These are the so-called fireproof buildings. The Jenkins Building, where the fire first started, and several smaller ones were entirely consumed. The lessons of the fire are, therefore, confined to the two Horne Buildings and the Methodist Building.

The location of these buildings and their relations to each other are shown on the map of the fire district, Fig. 1.

The Horne Store Building was built in 1893. It is six stories high, without partitions, and with an opening in the center 22 ft. wide and 50 ft. long, extending from the first floor to the top story, surrounded on each floor by an iron balustrade. There were also four passenger elevators on one side of the building, with a grand staircase between them. The opening in the floor made by these passenger elevators and by the staircase taken together was almost as large as the opening in the center of the building. Their location is shown on Fig. 1, and more particularly on Figs. 3, 4, 5 and 6. Undoubtedly, these vertical openings produced a draft, fed from every broken window, which intensified the heat of the fire and its destructive effects manifold.

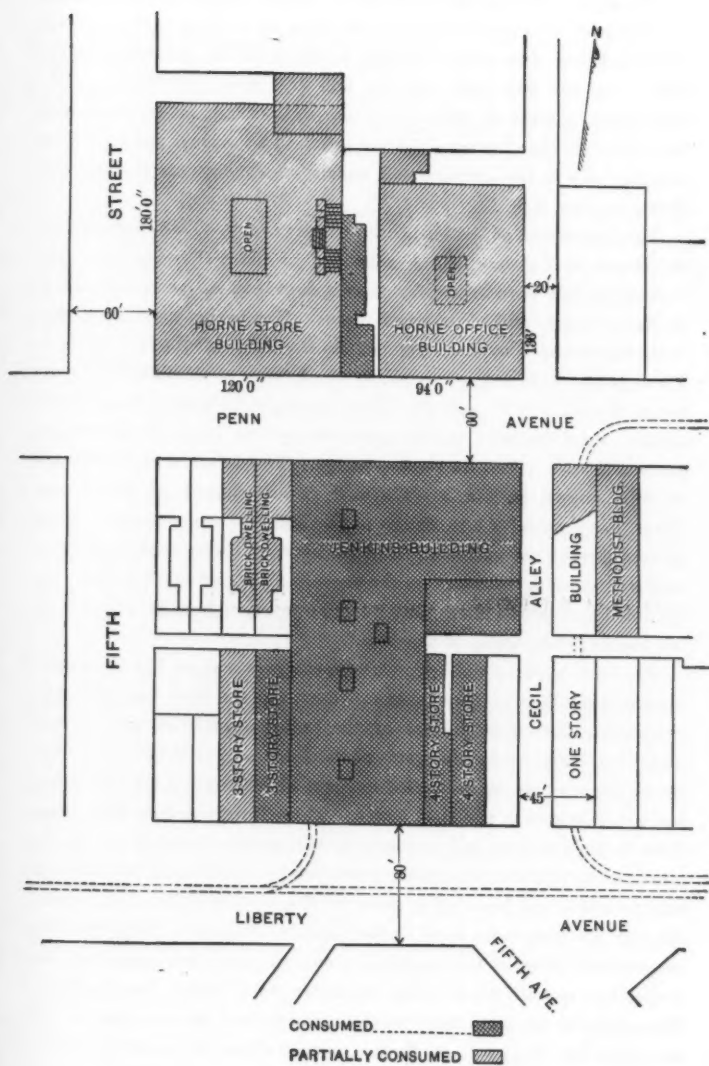
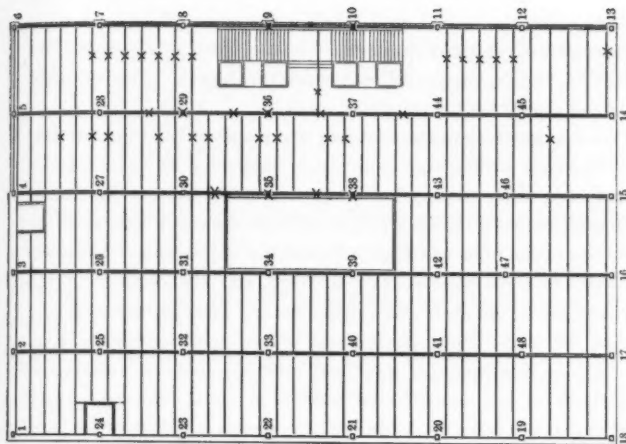


Fig. 1.

The entire building was occupied by Horne's retail dry goods store. The windows on Penn Avenue are as large as it was possible to make them, and they were entirely unprotected, either by shutters or sprinklers. All the floors and the east and west walls were supported by steel columns made of Z-bars and plates, the same, or approximately the same, as the Carnegie "Standard." The arrangement of these columns and of the girders and beams which support the floors is shown in Figs. 2, 3, 4, 5, 6 and 7.

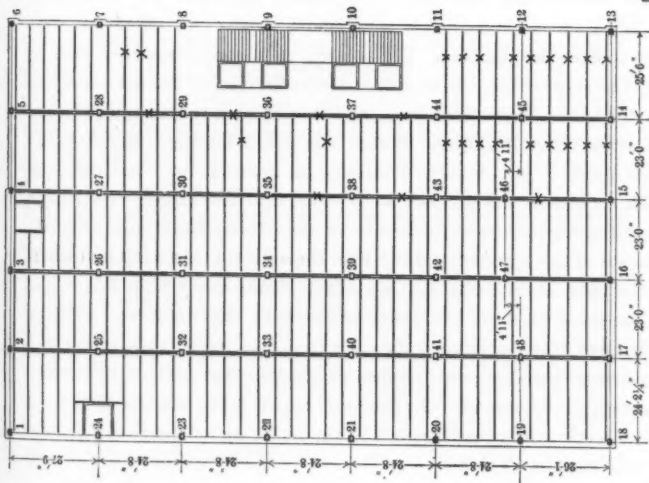
The framework of the building was very heavy. These figures show the beams and girders which remained in place after the fire. The interior girders were 24 ins. deep, with double 22-in. web plates, 3 x 3-in. flange angles and 15-in. cover plates. The beams were all 15 ins. deep, carried on brackets riveted to the side of the box girders. These beams were not connected to the girders at all through the top flange or web, and by only two rivets through the bottom flange. The girders were fastened to the columns by two rivets in the bottom flange and two rivets in the top flange. The detail of these connections is shown in Fig. 8. The wall girders along Fifth Street were 20 ins. deep, with 3 x 6-in. flange angles and 7-in. cover plates. These girders carried the wall from floor to floor, and were completely covered by the brick masonry on the second, fifth and sixth floors. On the third and fourth floors they were, however, somewhat exposed on the inside to the action of the fire.

The east or party wall, shown with the west wall in Fig. 9, was also carried from floor to floor on the girders, but the front wall was self-supporting the entire height of the building, and the rear wall was nearly so. The horizontal parts of the front wall at the floor lines between the windows were carried on iron lintels resting on the piers, and not fastened to the steel frame. These lintels on most floors were close to the windows and exposed to the action of the fire. In the fourth story they were partially protected by a course of terra cotta, but the latter was fastened in place by iron anchor bolts which passed through the terra cotta so as to be themselves exposed. Fig. 10 shows two sections through the rear wall, a part of which was supported on iron at the second floor. This is shown by a dotted line in Fig. 1. The ceiling in the sixth story was suspended from the roof beams. It was composed of $1\frac{1}{2} \times 1\frac{1}{2}$ -in. T-bars, spaced about 12 ins. apart, carrying a solid tile about $1\frac{1}{2}$ ins. thick.



2nd FLOOR FRAMING
FIG. 3

NOTE: THIRD FLOOR ABOUT THE
SAME AS SECOND FLOOR.



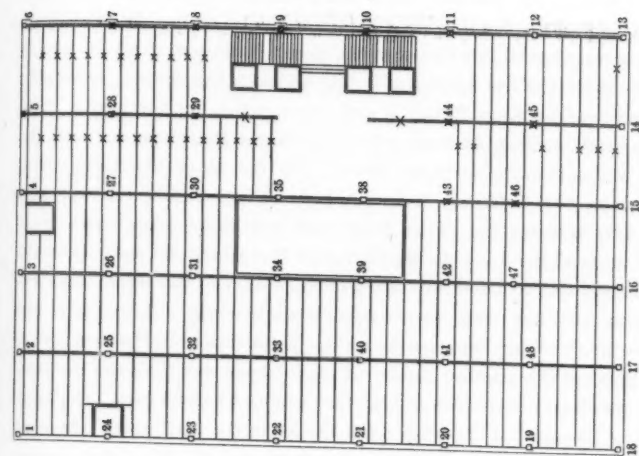
1st FLOOR FRAMING
FIG. 2.

The street walls were faced with pressed brick and terra cotta trimmings above the second floor. Below the second floor these walls were finished with Indiana limestone. The cornice at the roof level was made of copper, supported on wooden outriggers. The sidewalk was made of stone, resting on steel beams.

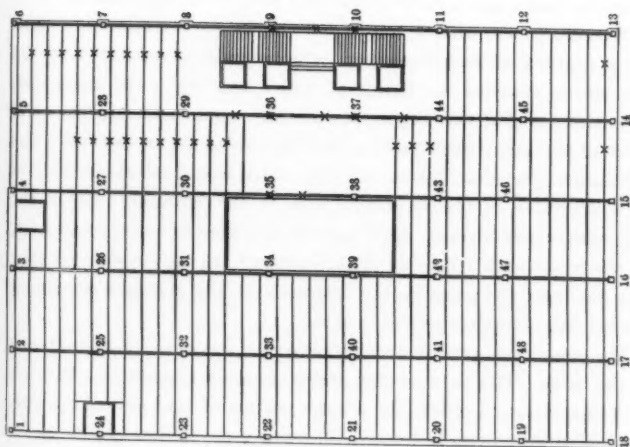
All the fire-proofing in the building was made of hard-burned material. The floor arches were 9 ins. deep, supported at each side by skewbacks especially designed to cover the entire side of the beam, and the joint between the arch proper and the skewback was made so that the top of the arch was flush with the top of the beam. The walls of all of this material were about $\frac{5}{8}$ in. thick, and the sections of the arches were of the old style side construction. The columns were covered with tile 2 ins. thick, having one hollow space and walls $\frac{1}{2}$ in. thick. All of this material was well erected. The floor sleepers, spaced about 14 ins. apart, were bedded in cinder concrete which covered the arches 4 ins. in depth, and the floor was finished with hard pine. This construction is shown in Fig. 11.

The first fire alarm was a little before midnight on the night of May 2d. The Jenkins Building was occupied by the Jenkins Wholesale Grocery Company, which carried a very heavy stock of oils and other things which were extremely inflammable; moreover the interior of the building was constructed entirely of wood. An effort was first made to save this building, but as soon as it was determined that it would be impossible, the attention of the firemen on Penn Avenue was directed to the Horne Buildings, and they started to carry hose to the roof of the Office Building. Before this could be done, however, the entire front of the Jenkins Building on Penn Avenue fell into the street. The fire was pushed, as it were, into the street. Its flames leaped entirely across to the fronts of the Horne Buildings, consuming some of the apparatus of the Fire Department, cracking and melting the glass in the windows, and setting fire to everything that could be consumed in these buildings adjacent to the windows. With a suddenness that can scarcely be conceived, the entire contents of the Horne Store Building were on fire, and in less than half an hour they were entirely consumed. On the four upper floors scarcely a vestige of woodwork of any kind was left in the building, and on the two lower floors it was almost as bad.

The tank on the roof fell to the first story and carried with it a



5th FLOOR FRAMING
FIG. 5.

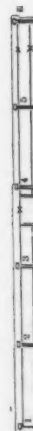


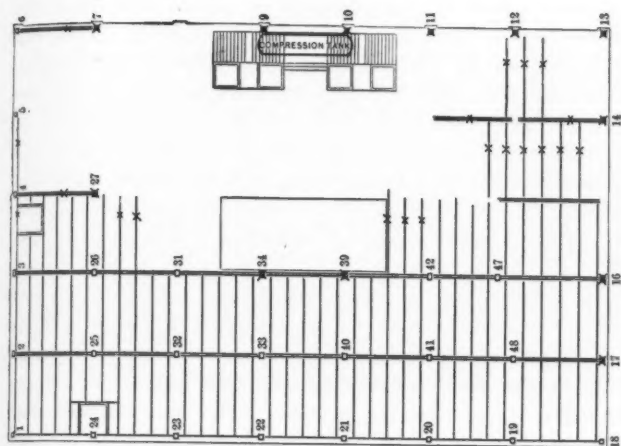
4th FLOOR FRAMING
FIG. 4.

large section of the steel construction, bending, tearing and breaking the adjacent columns and beams and pushing out the adjoining wall. The front of the Jenkins Building fell about 1 o'clock. Practically no water was thrown into either of the Horne Buildings until the fire in those buildings had spent itself. By 3 o'clock the firemen were able to get into the Store Building and throw water on the vaults. The face brick on Penn Avenue on both the Horne Buildings endured the fire well and was injured but little. The cut stone and terra cotta, however, were both very badly cracked and flaked off by the heat, and on this account the entire front wall had to be taken down, that which stood the fire well, together with that which did not. It would be interesting to know how much of this injury to the terra cotta was due to the water being thrown upon it while it was hot, but it is impossible to get any information on this point that would be conclusive.

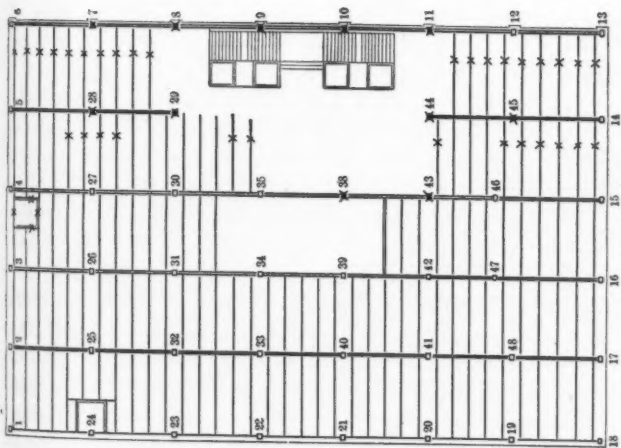
Some of the exterior lintels, where the span was long and the iron not very heavy, were bent so that they cannot be used again. The light T-bar framing for the suspended ceiling in the sixth story was bent and warped by the heat so that it will have to be taken out. Some of the lighter framing around the opening in the middle of the building was also injured. All the beams marked on the plans with a cross need straightening or fixing in some way before they are used again, while the beams and girders completely destroyed, and omitted from the framing plans, will of course have to be of new material. This data is reproduced from the report of the engineers appointed by the adjusters to examine the buildings and decide upon the exact loss. From the basis of this report the author would estimate the total value of the steel work in the building to be about \$80 000. The engineers reported a loss of \$18 530, which would be about 23% of the whole value of the structural iron in the building. All of the iron, even where covered, must have been heated to a very great heat, for where the tank fell some of the columns are bent as though they were wax, and the paint on the ironwork of the columns remaining covered also shows the evidence of it.

The cinder concrete over the floor arches was entirely decomposed by the heat. The tops of the arches which remained in place are everywhere in good order, but a large portion of that part of the arch that makes the ceiling is broken off, leaving the hollow spaces in the arches opening out into the story below. The skewbacks are also





ROOF FRAMING
FIG. 7.



8th FLOOR FRAMING
FIG. 8.

broken badly. In general, the covering of the columns in this building remained intact, but the plastering was ruined everywhere. All of the fire-proof in the building will have to be replaced; the east wall back of the elevators, which was pushed out of plumb by the falling tank, will have to be taken down and rebuilt, and repairs will have to be made in the Fifth Street wall. The cornice is a complete loss, largely owing to its being supported with wood. Nearly half of the roof was entirely torn out by the falling tank, but where it remained in place it seemed to be uninjured. The rear windows were provided with wooden shutters covered on both sides with sheet iron. The wood in all of these shutters was charred; and the iron was warped badly, though in almost every case the shutters held in their places until after 3 o'clock, when the fire was entirely under control. Without question they must have aided greatly in preventing the fire from spreading to the adjoining buildings in the rear.

Plate III, Fig. 1, shows the condition of the Store Building after the fire, and Fig. 2 is a view on the first floor of the same building looking from the center of the building towards the fallen tank, which shows quite clearly in the background. This picture also shows the construction of the light court and the railing or balustrade which surrounded it. Plate IV, Fig. 1, is also taken on the first floor, but looking in the opposite direction. It shows the ceiling and some of the broken tile. The floor arches did not endure the fire as well on the upper floors as they did on this. Plate IV, Fig. 2, shows in the foreground how the terra cotta was flaked off and broken around the windows in the Store Building. In the background on the right it shows the ruin of the grocery store, the one-story building through which the street cars pass, and the side front of the Methodist Building. This picture was taken several weeks after the fire, and the repairs to the window frames and windows in the latter building had already been completed.

The Horne Office Building was not as large as the Horne Store Building, and was only four stories high. It was built in 1894. The entrance to the office portion of the building, the third and fourth floors, was on the extreme western side of the building. In the basement, in the first story, and in the second story, the remaining portion of the building was divided into four parts by solid partitions extending from the front to the rear of the building. The western part was

PLATE III.
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PURDY ON FIRE-PROOF CONSTRUCTION.



FIG. 1.



FIG. 2.

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occupied by a drug store, the part adjoining this by a millinery store, the next part by a carpet store, and the eastern part by a china store. Each of these stores occupied its apartments in the basement and in the first and second stories. There is also a court in the building similar to that in the Store Building, but it only extends to the third floor.

The evidence of the firemen agrees with what the very nature of the construction would indicate as to the way the fire burned in the two buildings. In the Store Building the draft was in from the outside and up through the center. In the Office Building it was directly through these tunnel-like shafts on the first and second floor from the front to the rear of the building. Each floor of each store was like a

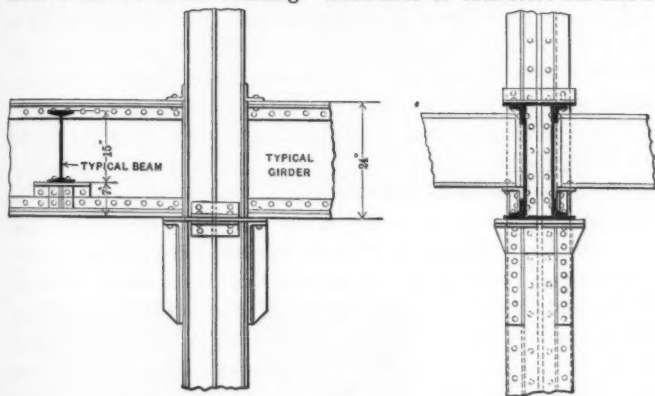


FIG. 8.

long flue, and all the contents and woodwork used in the construction were entirely consumed.

In some respects the construction of the building was similar to the construction of the Store Building. The floors were carried on 15-in. beams and Z-bar columns; they were also covered with cinder concrete and finished with wood flooring. The floor arches were 9 ins. deep, supported on skewbacks similar to those in the Store Building. The ceiling of the top story was made of light blocks of fire-proofing supported on T-bar construction. In other respects, however, the construction was radically different from that in the Store Building. The girders were made of double 20-in. beams. The exterior walls

were self-supporting. The floor arches were end construction instead of side construction, and, what is most worthy of notice, they were made of porous material instead of hard-clay material. A section of the floor is shown in Fig. 12.

The column covering, the ceiling of the top story, and the partitions were also made of the porous material. The column covering, however, was about 1 in. thick and solid, instead of 2 ins. thick and hollow. The walls of the floor arches were generally $\frac{3}{4}$ in. thick. All the partitions in the building were supported near the floor on a wooden frame. The front wall of the building was finished with Indiana limestone up to the second floor, and with pressed brick above the second floor. Three of the piers extended down to the sidewalk, and three of them started at the second floor and were supported in the first story by cast-iron columns. Plate V gives two elevations of the front of this building, showing these features of the construction, and the division of the building into the entrance and four stores.

Owing to the partitions on the third and fourth floors the fire did not do its work as completely as it did in the story below, but everywhere in the front of the building and in places entirely through the building every vestige of woodwork was completely consumed. This was particularly noticeable wherever the fire had a chance to get a draft through the building. In the stores and in the offices, wherever the fire burned the hottest, the woodwork was so completely burned out that nothing was left of the floor sleepers, which were almost completely bedded in concrete, and the framework in the partitions was also entirely consumed. Plate VI, Fig. 1, shows a corridor on the third floor where the partitions obstructed the progress of the fire most, and yet it will be noticed the wood was nearly all burned through.

The steel construction is almost entirely uninjured. A few angle bars about the court and a few lintel beams in the front wall are all that will need replacing, and this will cost only a few dollars. The floor arches were also in good condition. The damage is almost entirely confined to the bottom of the skewbacks which covered a portion of the beams. This is shown quite clearly in the illustration of a portion of the ceiling in the second floor, in Fig. 2, Plate VI. This picture is taken in about the worst place in the building. The bottoms of the tiles in the arch proper were not broken out as

PLATE IV.
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FIG. 1.



FIG. 2.

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AT THE BAR OF THE HOUSE OF COMMONS
IN THE MATTER OF THE
PETITION OF THE
[illegible]

EXTERIOR; BUILDING LINE BETWEEN COL'S 1 & 4

NO

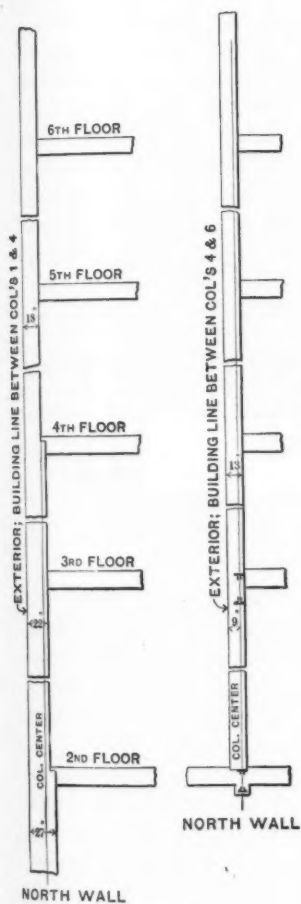


Fig. 9.

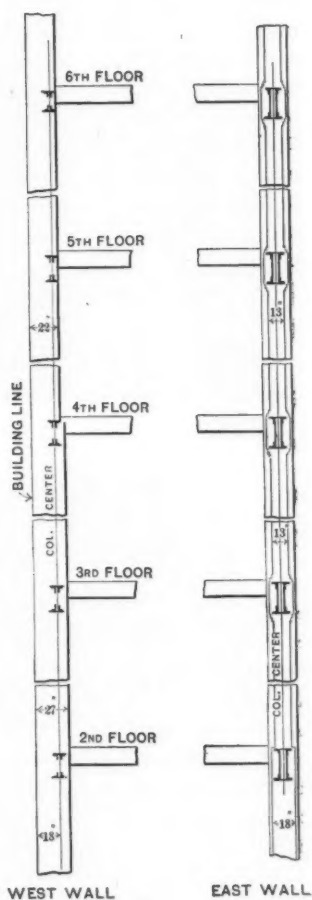


Fig. 10.

they were to a great extent in the Store Building. The column covering also stood the fire remarkably well, considering the shape of the tile that was used for the purpose. The partitions between the stores nearly all remained standing in spite of the fact that where the wood burned out the opening extended from column to column. A fair example of this is shown in Plate VII, Fig. 1. Some of the partitions in the offices stood the same way, but many of them sagged down when the framework burned out, and a few were entirely broken down. The cinder concrete was also entirely ruined, but the ceiling in the fourth story was injured very little, and the roof, excepting the skylight and some of the flashing along the front wall, is left as good as before the fire. Even the light trusses over the court are entirely uninjured.

The Methodist Building was also built in 1894. It is long and

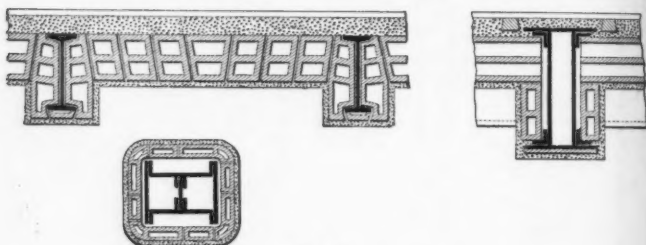


FIG. 11.

narrow and very much smaller than either of the other buildings, covering only about one-fourth as much ground as the Horne Office Building, and about one-sixth as much ground as the Store Building. It is eight stories high, occupied by a book store on the first floor, and by offices on the other floors.

By reference to Fig. 1 it will be seen that the broad side of the building was exposed to the fire. The offices were all on this side of the building running back to a hall and stairway on the other side. The construction of the building in almost every particular was different from that of the other buildings. The exterior walls were made of brick with sandstone trimmings, self-supporting. There were no interior columns in the building, but columns in the walls supported 20-in. beams spanning the entire width of the building. These beams were supported about 16 ft. apart, and carried floor arches without

PLATE V.
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PURDY ON FIRE-PROOF CONSTRUCTION.



FIG. 1.



FIG. 2.

the use of joists or other intermediate beams. These floor arches are composed of a solid bed of concrete about 8 ins. thick, made of Portland cement and slag, and strengthened with imbedded wires extending over the tops of the 20-in. beams. The whole construction is so designed that the top of the concrete is about flush with the tops of the beams, as shown in Fig. 13. That portion of the beams projecting below the arch is also boxed in with concrete of the same kind. All the partitions in the building are made of 2 x 4-in. wood studding in the ordinary way, covered with wire lath on both sides and plastered. The spaces between the studding are not filled. The ceiling of the top story is made of wood, suspended and covered with wire lath the same as the partitions.

The fire seems to have been greatest in the top story and nearly as bad in the two stories below. The windows in the east wall of the Jenkins Building, facing the Methodist Building, were provided with

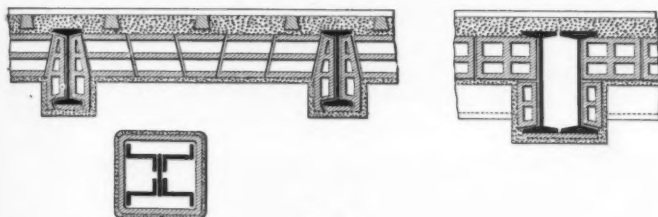


FIG. 12.

iron shutters. The rear portion of this wall did not fall during the fire. This was a great protection to the Methodist Building. The front portion of the east wall of the Jenkins Building fell shortly after the wall facing Penn Avenue fell, and nearly all of the window frames in the Methodist Building at once took fire. As the entrance to this building and the stairs and halls are all on the side furthest from the fire, the firemen could take their hose into the building and fight the fire on each story from the inside. There was no room in this building where the woodwork was entirely consumed. The wood in the floors was burned only in a few places. The ironwork and the concrete in the floors were not seriously injured. A very small expense will make the former as good as new, and all of the concrete floors can be used again, though the owners are putting in some additional beams for their support. The floors are deflected. They have evidently

been so since the building was erected, though the deflection seemed to the author to have been somewhat increased by the fire. The partitions offered but little resistance to the fire and are badly damaged wherever the fire made an entrance to the building. The ceilings also suffered severely.

A careful study of the illustrations from Plate VII, Fig. 2, to Plate IX, Fig. 2, inclusive, tells the story of the fire in this building better than words. Plate VII, Fig. 2, shows the rear part of the east wall of the Jenkins Building still standing after the fire, and the firemen throwing water on the fire from the roof of the one-story building, between the Methodist Building and the grocery. Plate VIII, Fig. 1, shows one large room on the eighth floor, the interior of an architect's office; Fig. 2 on the same plate is a room on the seventh floor. Plate IX, Fig. 1, is another room on the seventh floor, and Fig. 2 is a room on the sixth floor.

So much for the construction of the buildings, the fire and its

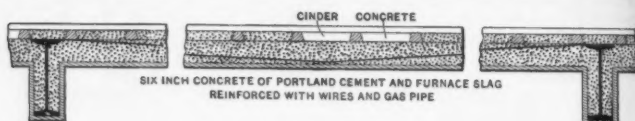


FIG. 13.

effects. In entering upon a discussion of the relative merits of the different buildings, the different materials used in them, and the lessons taught by the effects of the fire, it may be well first of all to call attention to serious faults in the construction in all three buildings, which were inexcusable and greatly increased the loss pertaining to the buildings themselves.

The sound value of the Store Building is estimated by the insurance adjusters to be \$367 980, while the total damage is given at \$206 747. This is exclusive of boilers and dynamos. The loss to the steel construction, as reported by the board of engineers appointed by the adjusters, as stated before, was \$18 530, that is to say, the loss in the steel construction was about $8\frac{1}{2}\%$ of the whole loss, or, as previously stated, about 23% of the whole value of that part of the construction. Out of 336 columns in the building, counting each story separately, 13 were entirely destroyed, and 48 were injured so as to require fixing and re-erecting. Four heavy girders were also ruined,

PLATE VI.
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FIG. 1.

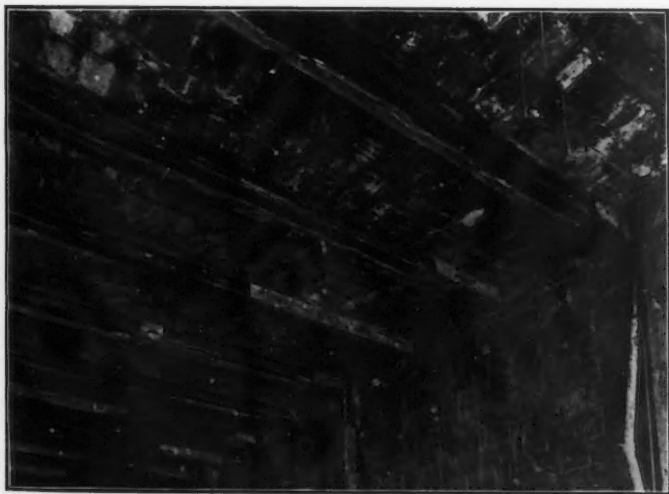


FIG. 2.



and 18 others were injured. These figures are made up from the engineers' report before referred to.

The location of the tank on the roof is shown in Fig. 7. It was 6 ft. in diameter and 25 ft. long, made of steel plates $\frac{1}{4}$ in. thick in the cylinder and $\frac{1}{2}$ in. thick in the heads, and had a capacity of about 5 000 galls. In working, however, only about half of this should be figured on, and the total weight of tank and contents when it fell was therefore probably not more than 30 000 lbs. It was supported by roof beams which were carried at one end by the girder between columns 36 and 37, and at the other end by the wall girder between columns 9 and 10, and enclosed with a tile wall and asphalt roof. The four beams under the tank were 15 ins. deep. The roof here, as elsewhere, was protected only by the suspended ceiling. None of the roof framing was fire-proofed, and no exception was made of the beams under the tank. The intensity of the heat at this point was also greater, for it was at the top of the flue. Whether the beams or the columns gave way because the factor of safety in them was not as great as it should have been, or the heat was simply too great for anything to withstand, and the absence of fire-proofing is alone to blame, matters little. The fact remains that good fire-proofing would undoubtedly have saved the tank, and if the tank had not fallen at all, the loss of the steel construction would have been, as estimated by the adjusters, not more than 5 per cent.

A careful examination of Figs. 3, 4, 5, 6 and 7, will show that more than one-third of the roof was torn away, as were large areas on all floors, decreasing from top to bottom. One cannot help asking why beams so distant from the tank were torn out by the fall. It should be particularly noticed, too, that the tank fell in a comparatively open place where the framing laterally was much weaker than elsewhere. Why, also, did the beams give way more than the girders, and why was the wall bulged out at all? It seems to the author that if the beams, girders and columns had been connected to each other, somewhat proportionately to the strength of the members themselves, the tank would have gone down through the stairs with very little injury to the structural iron work or the wall, and, at the most, this part of the loss would not have exceeded \$5 000. As it is, 16% of all the beams had to be replaced, and 14% of them had to be straightened or fixed. The use of $\frac{1}{4}$ -in. metal in the top tier of columns is also, to say

the least, a dangerous practice. It is more than possible that these columns were the first members to give way.

Another particularly discreditable piece of work in this building has already been referred to, the use of wooden outriggers to support the copper cornice. The loss on the cornice is not given, but it must have been quite an item.

In the Office Building there is another grievous fault in construction, but in this case in the partitions. It is a fault, too, which has been repeated again and again in buildings which are counted as fire-proof. All the partitions in this building must be taken down, and it is a pity, too, for, except the injury due to the burning of the wooden frame on which they rested, most of them were as good after the fire as they were before. This frame was put in to nail the baseboard to, but was not needed, for the porous material in the partitions will hold a nail nearly as well as wood.

The greatest fault in the construction of the Methodist Building also concerns the partitions. If this building had had a quarter of the heat that the other buildings had, every partition would have been completely destroyed. The fire seems to indicate that plastering will not prevent the heat of a great fire from charring a wooden frame behind it, even if it does not come off and expose the wood, and such work is not fit to be reckoned as fire-proof construction. All of these are faults which were scarcely matters for question. The knowledge and experience of architects and builders had already covered this case, and the fire can now only emphasize it.

Nevertheless if all these faults in construction had not existed, the buildings would have been injured, and the contents of the stores, at least, in both the Horne Buildings, would have been burned. They offered little resistance to fire because the glass in the windows broke into pieces and in some places melted, immediately after the front wall of the grocery building fell into the street.

The firemen could not for a moment stand the heat, which they claim was hotter than any of their oil fires. They scarcely saved their engines and their lives, and they had, in some cases, to turn the water on each other, and even then some of them were burned. The heat on the building on the opposite side of Fifth Street, which was exposed to only a fraction of the intense heat of the grocery store, turned the water thrown on it to steam, so that the firemen worked at a disadvantage



FIG. 1.



FIG. 2.

in not being able to see well. Under these circumstances, there could be no hope for the contents of either of the Horne buildings.

It seems, therefore, as if the first problem is the protection of large windows, and that, perhaps, the most important lesson of this fire is the necessity of that protection. It is not so important in some New York and Chicago buildings as in cities like Pittsburg, for in the former there are so many incombustible and fire-proof structures that a heat great enough to break glass across the street is not likely to occur, whereas in smaller cities having only a few buildings of modern type, in many cases surrounded on all sides by buildings built largely of wood, the danger to glass areas is greatly increased.

It seems as if ingenuity ought to furnish some practicable scheme for protecting large window openings. The shutters in the rear of the Horne store did most excellent service and the covering was only thin sheet iron. Why should not all windows in fire-proof buildings be provided with iron window frames, and iron sash and metallic or asbestic rolling shutters of some character? The solid folding shutter is objectionable on front openings because it disfigures the building, and if they are on the inside of a window, they prevent a proper use of it.

Without question automatic sprinklers or other water safeguards against fire have had a large sphere of usefulness, and might be devised as a special protection to show-windows. It seems, however, as if the shutter should be of some solid material. Firemen would not hesitate to enter a store and fight any fire behind a solid barrier, and in all but the worst cases such assistance would scarcely be required. Besides this, if a solid barrier secured the protection, there might be no loss to contents; whereas the damage by water in a stock of merchandise might be as bad as the loss from fire. One of the principal points made in reference to the sprinkler is that a pail of water at the beginning will extinguish any fire and that the sprinkler itself furnishes that first pail of water. The automatic fuse is, therefore, made to act at a very low temperature, say 150° , while the heat on a show window in such a city as Pittsburg may exceed $1\ 000^{\circ}$, or, in rare cases, double that amount.

Some of the best buildings have iron window frames and sash, and other buildings with large windows, larger than these in Pittsburg, are provided with rolling shutters. Wood frames and sash are used,

generally because of their economy, and consequently it is not only a question of "how," but subsequently a question of persuading each owner to meet the additional expense.

Some reports of the fire have condemned the large openings, but who can say that the fire would not, under the same circumstances, have spread with equal rapidity through smaller openings. Reform in buildings cannot be conducted along lines which shut out the light or deprive the building of its architectural design. The end must be accomplished, if it is accomplished at all satisfactorily, by protecting the windows and not by changing their size. In dark cities, like Chicago and Pittsburg, the large light areas are exceedingly important and are one of the chief advantages of modern building methods.

Kindred to this evil of unprotected window openings is the open shaft through the center, which practically makes one room of the entire building. Indeed, so far as the progress of the fire is concerned, it is worse than one room. Insurance men have long recognized that large store buildings open over entire floors, and through all stories are a dangerous fire risk, and must remain so unless some satisfactory method can be designed of dividing the space either permanently or when not in use. The insurance adjusters in their report suggest that such light shafts might be protected by an asbestic covering made to roll up and come together in the center. Such an arrangement would close the shaft at each floor level. In this particular case the fire undoubtedly entered through the windows at one time on all floors. The open shaft did not prevent the destruction of the contents, but only intensified the heat on the upper floors. If, however, the fire should start in such a store on the lower floor, and was not almost immediately extinguished by a fire service of some sort, the chances are altogether probable that the open shaft would be the means of the destruction of the entire contents of the building; whereas, if the floors could be closed by some simple mechanism, such a fire could be confined to the floor on which it originated.

It seems to the author that, however perfect a scheme can be worked out for fire protection by the use of water, the importance of separating floors from each other, at least in an emergency and when not in use, and indeed separating stores into parts in the same way, would still be vitally important.

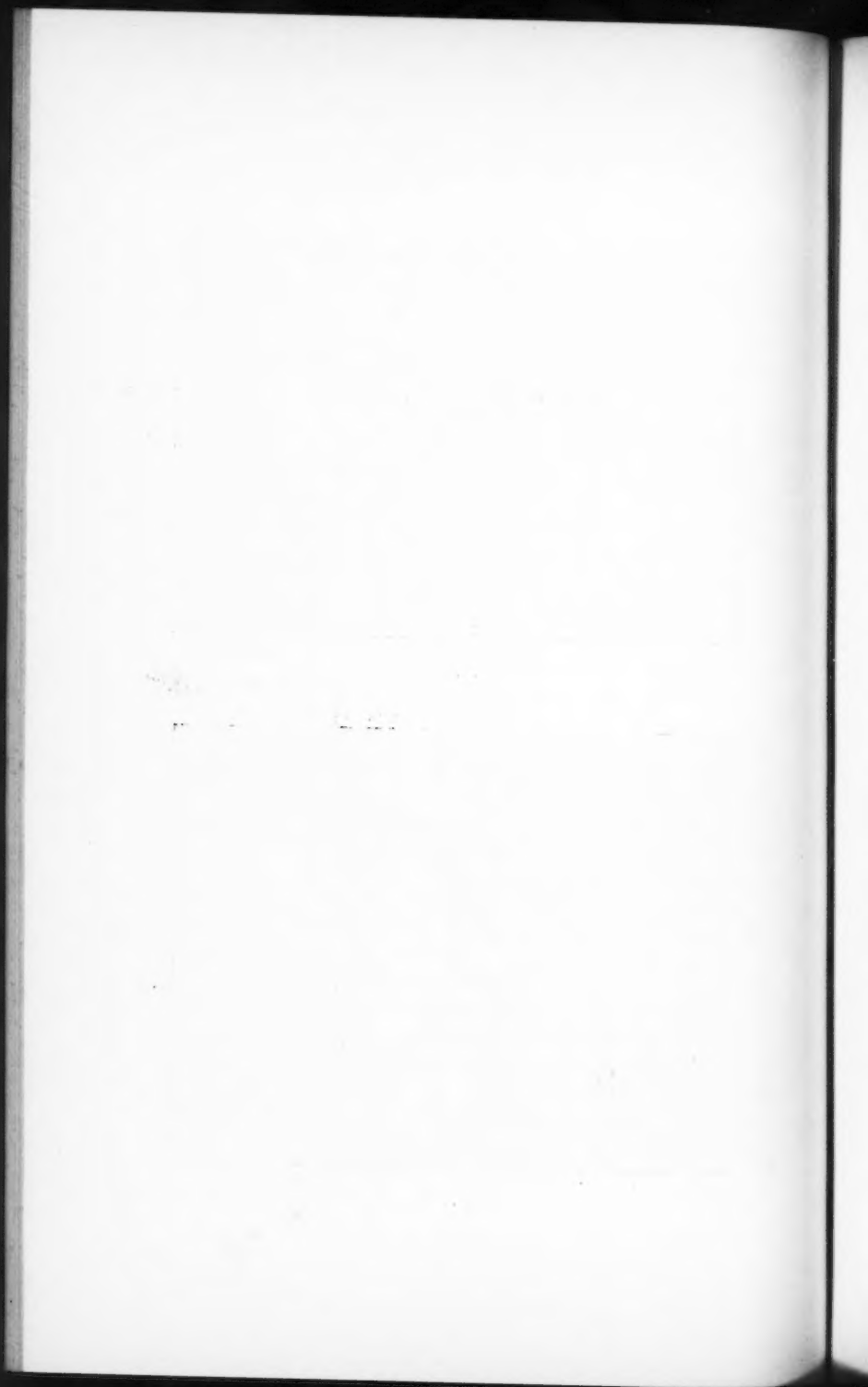
PLATE VIII.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXXIX, No. 823.
PURDY ON FIRE-PROOF CONSTRUCTION.



FIG. 1.



FIG. 2.



One of the most important object lessons relating to the fire pertains to the fire-proofing.

The fire teaches nothing as to the real fire-proof qualities of good concrete in floor construction, for the floors in the Methodist Building were not subjected to a real test. The heat on the outside of the building was only a fraction of what it was on the other buildings, as testified to by the firemen and by the fact that the stone trimmings in the exterior walls exposed to the heat were injured in only three small places, while the fire on the inside was confined to an area entirely controlled by the fire department. Whether ordinary concrete, or, for that matter, concrete of any kind, will resist more fire and cold water than brickwork or other forms of burned clay is undetermined and debatable. Certainly this fire does not prove that it will or that it will not.

As between the burned material and the porous, however, the superiority of the latter as now manufactured and used was clearly illustrated. The author ventures the definite statement, that partitions of 4-in. hollow porous material made of sawdust and clay properly manufactured and properly put in place, column covering made in the same way at least 3 ins. thick, and floor arches of the same material deep enough for flush ceilings, with properly designed skewbacks and beam flange protection, will stand any possible combination of heat and water, without material injury. It seems to him that the fire in the Athletic Club Building at Chicago proved this, as does the fire at Pittsburg.

The same thing cannot be said, however, in regard to hard-burned clay material, as it is now manufactured, especially in the West, where, in the interest of economy, it has been made lighter than in the East, though in theory it ought to make satisfactory resistance to fire, for it is incombustible and hardened with heat, and brick which is made in the same way can be relied on to stop a fire. Yet not this fire alone, but others have demonstrated that the hard material will crack and fall to pieces under great heat, even if it is not suddenly cooled with water thrown upon it.

The fire-proofing work in the store, both in the arches and around the columns, was erected well. Indeed, it was probably erected better than in the average New York building, and the damage to the fire-proofing in that building is primarily due to its being hard material

instead of porous. The covering of the girders and beams which projected below the ceiling line was pretty generally broken, and this must have been due in a large measure to the fact that the ceiling was not a level surface, though the loss was, without doubt, increased on account of the very few divisions in the tile and the very thin walls. The material used in New York is all thicker and heavier than this was, and on that account would probably stand a fire better. That the damage to the fire-proofing is primarily due to its being hard tile instead of porous is, however, shown by a comparison between the two Horne Buildings. In both cases the ceiling was paneled. In the Store Building the bottom of the hard tile arches was broken by the fire, whereas in the Office Building there was scarcely any injury of that kind. The insurance adjusters state that there is only a salvage of 16 $\frac{1}{2}$ % in the fire-proofing of the Store Building, but that they believe if the tank had not fallen, the salvage would have been at least 50 per cent.

A satisfactory fire-proofing material when properly constructed in all its details should not suffer a loss of more than 1% or 2% at the most.

The fire-proofing in the Office Building suffered much more than this, but in every case there is a special cause for the injury, entirely independent of the quality or texture of the material. The adjusters report 43% loss on the partitions, and this is low when it is remembered that every partition in the building was left unsupported by the burning out of the wooden frame. The column covering resisted the fire unexpectedly well, but the single thickness of material makes a wretched covering, and it should all be replaced with hollow blocks. In places, as shown in Plate VI, Fig. 2, the skewbacks covering the beams projecting below the arches suffered severely. If the insurance companies were required to replace all these broken pieces, it would necessitate the removal of arches which were entirely uninjured. The author has not been able to account for the large percentage of damage allowed by the adjusters on this part of the fire-proofing, 33 $\frac{1}{2}$ %, on any other supposition, for in his examination he found practically none of the arches injured, and the contractors in rebuilding have furnished only 300 ft. of new arches, while there are 40 000 ft. in the building.

Besides this, which is perhaps the most important observation in

PLATE IX.
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FIG. 1.



FIG. 2.



regard to the fire-proofing, the following conclusions seem also to be warranted.

The breaking of the hard tile arches on the bottom is due to the inability of the materials to withstand inequalities of contraction and expansion, and it breaks in the corners, both because the strain is greatest and the tile is weakest there. There is an inequality of expansion because it is heated only on one side. The strain is greatest in the corners because the expansion of one side tends to shear that side from the adjoining ones, and it is weakest at the corners because if there is any initial stress in the material it would more naturally occur there than elsewhere, while the very fact that it breaks in that particular place more than anywhere else indicates that it is lacking in strength along the edges. The report of the board of expert engineers appointed by the appraisers furnishes some valuable facts, but some of their observations seem to the author extremely fallacious, and quite so in regard to this point. They state in effect that the scaling off of the lower web of the floor arches is due to the lateral motion of the iron work caused by the heat of the fire. A panel surrounded by iron will enlarge in area if the iron expands, and if it is true, as they claim, that the iron expands more than the arches, the process of expansion would seem to relieve the arch, in whole or in part, instead of bringing any strain to bear upon it tending to its destruction. The damage to the tile is also not due to the subsequent process of contraction, for, as a matter of fact, the damage to the tile occurs during the fire and not after it.

The tendency of the times is to make the material too light. If the walls of the material were made thicker, it certainly would add strength. Possibly, also, if the angles on the inside were rounded more, the strength of the corners would be increased. Checks and cracks in the corners of the blocks as delivered from the factory may not be particularly objectionable, so far as support to the floor is concerned, but they are objectionable in resisting fire effects, and such tile will go to pieces sooner than that which is free from such imperfections.

Possibly some clays of which hard-burned fire-proofing material are made have more strength than others, and, on this account alone, the effect of the fire in one case can be no certain criterion of what the exact effect will be in another case, and the thickness of the walls and

the various parts of the material might possibly be lighter with some clays than with others.

Unbroken flat ceilings should always be preferred to panel work with beams projecting below, no matter in what way they may be protected. This fire greatly emphasizes this fact. The exposed area is increased when floors are built as they were in the Horne Buildings, and, besides, the panel forms a pocket which confines the heat and makes it more effective. An even surface deflects heat as it does light, and if the surface is even, the covering of the beams, where protection is most needed, will not suffer the worst punishment, as it did in the Horne Buildings. The fact that the beams which were uncovered by the action of the fire were not deflected and ruined is no reason why they should not be covered so that the tile will not come off in any kind of fire.

The bottom of the arch should also be low enough under the beam to permit the bottom flange to be covered with a hollow tile, or, at least, with a solid tile having an open space between the covering and the beam. As the material is now manufactured, this is rarely accomplished, and the workmanship in putting the beam covers in place is often bad. It seems as if there might be an improvement in this direction, and that the material should be designed in such a way that it will not only be theoretically good, but so designed that the beam cover cannot possibly be improperly placed.

All partitions and all column covering should be built on the arches. Cinder concrete which will crumble away is not much better for support than wood which burns away. Builders may object to such a provision, but it would not be a great hardship or add materially to the cost.

Wood should not be used in partitions in any way whatever. Iron should be used to frame all openings.

The insurance adjusters have also called attention to the fact that the damaged limestone in the first story of the Horne Buildings requires the pulling down and rebuilding of much brickwork which was entirely unharmed. They state that there would not have been more than 15% loss in the brickwork if other members had stood, whereas the loss is actually at least 40%, the excess being due, it is presumed, to the falling of the tank and the taking down of good walls on account of the broken terra cotta and stonework.

They also call attention to the broken sidewalk, which was a total loss, and state that if the beams had been filled in with brick arches and finished with cement, the loss would have been very small.

All experts who have examined into the matter carefully seem to agree that the fire demonstrated the success of the steel-frame method of construction.

The general public is not sufficiently informed or is not careful to discriminate as to exactly what is meant by the words fire-proof construction, and so it naturally questions the success of fire-proof buildings. If by fire-proof buildings are meant those that will prevent inflammable contents from burning, and, to some extent, from injuring the structure itself, when the fire is once started on the inside, the answer must always remain "no," and the public might as well understand it. The expression "fire-proof building" should properly be defined as a building which will not burn, no matter how great a fire, it may be exposed to from without, and which will confine an internal fire to any room in which it occurs, without material injury to the rest of the structure.

In this sense of the word, buildings can be made fire-proof, and the fire at Pittsburg rather confirms that opinion than otherwise.

No attempt has been made in this paper to get at the exact temperature of the fire, first, because the examination of the buildings was made too late to do so with any degree of satisfaction, and also because the conclusions arrived at are not necessarily dependent upon the exact temperature. In every discussion it must be taken into account that no two fires are alike. It is the unexpected that always happens, and the only measures that can be depended upon are those designed to meet extraordinary conditions which must always be to a certain extent assumed.

In conclusion, a recapitulation of the most important points intended to be brought out by this paper may not be out of place.

The best design, the best specifications, and the best workmanship in every detail of the construction of a building, are quite essential to making it a fire-proof structure which can be depended upon in any emergency.

The whole exterior of a building should be built of materials that will not be injured by heat. This fire would point to brick-work as the most desirable material, and without question throws

terra cotta under a cloud. This observation should cover the windows as well as the walls, and points to something new and better than has yet been used to any great extent in building operations.

Large store buildings, open over entire floors and through all stories, must always be a dangerous fire risk, and if it is important that large department stores should occupy such quarters during business hours, the only way to give them any satisfactory security against fire must be in subdivision of departments with fire-proof curtains or some other movable divisions which can be quickly and easily operated.

As now manufactured porous tile or terra cotta fire-proofing can be relied upon to protect the steel construction, while the hard-burned material cannot be depended upon with the same certainty.

Woodwork covered with wire lath and plastering is not fire-proof construction, and the efficiency of concrete in floors was not tested by this fire.

DISCUSSION.

HENRY S. PRICHARD, M. Am. Soc. C. E.—One of the features frequently overlooked in the discussion of materials used in fire protection is the degree of resistance they offer to the transmission of heat to the parts they are supposed to protect. When the parts to be protected are of great importance, and the fire-proofing is not so far injured as to expose the metal, the resistance to the transmission of heat offered by the fire-proofing is of more importance than the resistance which the fire-proofing offers to being injured. It would be interesting to know to what extent the fire-proofing, where it has not been so seriously injured as to expose the metal work, has kept the heat from reaching the protected parts in the buildings that form the subject of this paper. Mr. Prichard.

That it is practicable to effectually protect floor beams from injury in an ordinary fire was shown by a five-hour fire test, with a maximum temperature of 2100° Fahr., made on May 20th, 1897, under the supervision of the Department of Buildings, New York City. In this test the beams, which were protected on the bottom and sides by about 2 ins. of a fire-proofing composed chiefly of plaster of paris, had no permanent set, and the paint on them was to all appearances uninjured, thus showing a protection which, as far as the speaker is aware, is much better than any ever obtained where the beams were covered with either clay or concrete.

HOWARD CONSTABLE, M. Am. Soc. C. E.—To avoid being misled, Mr. Constable. in studying fires and their effect on materials and construction, some evidence should be sought as to the nature and degree of the temperature reached, such as the glazing or melting of common brick or terracotta, the melting of brass, glass, cast-iron pipes, etc. For instance, in the case of the Methodist building and the other buildings, some information on this point is desirable. Fire-proof materials have different points of disintegration and fusion. The intensity of the heat may readily range from 1500 to 2500° Fahr., and many materials will stand heat for many hours, provided the temperature does not rise above the disintegrating or fusing point. If cast-iron pipes in the Methodist building or other buildings were melted, then the test was very severe; but if there is no proof of temperature, the test may not have been great. The speaker had made experiments and found that with a fire in a room about 12 ft. square and 10 ft. high there might exist differences in temperatures of nearly 1000 degrees. Most of the fire-proofing experiments have been made with a door at one end of a room or kiln and a flue at the other, allowing a draft of cold air to draw in over the flame, and between it and the ceiling.

The speaker had attended a great many fires and tests, and it seemed to him that some of the general deductions and comparisons

Mr. Constable. were erroneous, as the temperature, quantity and impact of the heat differed widely.

"Absolutely fire-proof" is a misnomer. Relative fire and water resistance is a more accurate and suggestive term to use in studying to improve the quality of buildings. The effect of the temperature and its gradual or sudden impact must be observed more carefully and also the particular shape or form in which it is proposed to use a given material.

The speaker made experiments some two years ago which satisfied him that porous terra cotta was a better fire and water resister than hard terra cotta, yet hard terra cotta in some simple shape was better than porous terra cotta in a more complicated shape. The same could be said of cements and concretes, and of the comparison between them and terra cotta.

As regards spaces left between the beam and the fire-proofing, the speaker thought that they might be dangerous, as he had seen cases where the flame had gone through and thus obtained a better opportunity to attack the iron; and in one case had cut off a tie rod, which caused a section of the floor to fall. Attention to good design and detail and careful inspection of fire-proofing work are much to be desired. There seems to be no reason why fire-proofing should not become a practical science instead of a crude art, so that fires may be confined to the limits of the room in which they start, and repairs amount principally to those of patching, plastering and decoration. At present, it is only too common to see "an absolutely fire-proof building" almost a total loss, and in other cases the main body, the beams and columns of a building, so injured that they need re-enforcing or replacing; whereas a little more care in the proportioning and inspection of the fire-proofing would have prevented any injury to the iron-work.

Recent laboratory experiments made by the speaker have done something toward a more intelligent study of fire-proof materials. They show that a great number of materials called fire-proof in reality differ enormously in their resistance to fire and water, and are by no means manufactured of uniform quality in these particulars. As regards strength for floors, provided there is good design and careful inspection of workmanship and materials, it is far less difficult to deal with than that of fire and water resistance. The margins are very much greater. The legal load for floors in New York City is 150 lbs. per square foot, which is equal approximately to 1 lb. per square inch. It is not difficult to secure materials and allow ample factors of safety to resist such forces, but fire-proofing materials do not afford such margins. A material that will stand 1 500° may disintegrate at 1 800° and fuse completely at some few degrees above that. The tests which have been conducted within the past two years in different parts of

the country, in the four-chimney kiln designed by the speaker, and Mr. Constable. with the application of the fire-stream and the use of the pyrometer (especially those conducted by the Building Department of New York City at Eighty-fourth and Sixty-eighth Streets) have been most instructive to any student of the subject; and it is surprising how few engineers and architects have been present at these tests so as to be in a position to make comparisons and exercise good judgment.

The tests have demonstrated the manner in which a fire can be confined by different kinds of floors; the manner in which beams should be protected, and the fact that, at present, partitions cannot be expected to stand as severe a test as floors. The advent of wire-glass as a great fire resister as compared to sheet glass or plate glass is a matter of much interest. The speaker has recently tested several materials used in wainscoting. The tests were continued for one hour at 2000° , then water was applied to each sample. The first test showed that the material was too brittle, and the manufacturer modified his mixture gradually until a much better degree of toughness was secured. This is a practical illustration of the importance of temperature in making improvement with certainty and without great expense. The estimation of degrees of heat by the eye, by pieces of metal or by a common pyrometer are excessively crude methods and may be misleading by 100 to 500° , which is sufficient to pass the point of disintegration or the point of fusion.

So many accidents have been caused by stair treads cracking that improvements in this direction are desirable. As regards the protection of iron the speaker thought it pretty well determined that at from 600 to 1000° iron and steel begin to lose their strength and need protection.

As regards the engineer in architecture and building, the speaker thought he had come to stay, and introduce those methods of investigation, testing and inspection, which have made bridge-building, ship-building and skeleton construction so successful. In reference to the construction of the testing kiln care must be taken with the doors, drafts, flues, the arrangement of grates, fuel, location of pyrometer, etc., to insure uniform temperature and reliable data for the comparison of tests.

In reply to a question by Mr. Prichard the speaker submits the information that in some thirty-five cases where the temperature ranged from 1500 to 2400° , the time of exposure being from one to six hours, the temperature of the upper flanges of 6-in. to 10-in. beams might be approximately placed at not much above 200 degrees. Magnesia and plaster are among the highest resisters of heat, but are more easily washed away by the action of water than terra cotta, ordinary good hard lime or cement plaster. In one case, where the beam was protected by 3 ins. of concrete, the fire was maintained for five hours

Mr. Constable. and the temperature went as high as 2300° and there was no practical or permanent set produced in the beam.

The length of floor sections tested by the speaker was 12 to 14 ft., full-size beams, full-size blocks, etc. Laboratory testing specimens 2 ins. x 4 ins. were used. In testing individual blocks, the shapes and sizes found in the market had to be taken. In designing, the material should first be studied, its molecular characteristics and behavior under fire and water, and its behavior when in certain shapes; then close attention must be paid to detail and workmanship. The action of certain materials on iron should not be neglected.

Terra cotta, although a splendid material, is often handicapped by the shape in which it is used and its poor modeling; good cast-iron work and pottery are instructive in this direction. The speaker thought, as regards cement testing, there was a good deal of irregularity of results due to the shape of briquettes, and that Mr. Whittemore, in designing a double-headed round briquette with a clutch for the same, had made a step in the right direction.

Mr. Freeman.

JOHN R. FREEMAN, M. Am. Soc. C. E.—In studying the ruins of a fire to determine the resistance offered by various materials of construction, it is of great importance to ascertain approximately the maximum continuous temperature, and the length of time that the members of the structure were exposed to this temperature. Commonly, a record, sufficient for purposes of comparison, will be found in the degree to which various substances have been melted or distorted by the heat, and in the depth to which exposed flat surfaces of wood have been charred or burned away, or in the diameter of pieces of exposed wrought iron, as horizontal shafting or pipes, which have become so softened by heat as to droop under their own weight.

In the fire under discussion, the photographic reproductions appear to confirm fully the author's conclusion that the system of fire-proofing in the Methodist Building received no severe test, and to demonstrate that the temperature therein was very moderate compared with that reached in many fires. It is also evident from the photographs that the duration of extreme heat was so short that it did not have time to soak in and reach the skeleton of the structure. For example: Plate VIII, Fig. 2, demonstrates that the heat in the middle of a seventh-story room, directly opposite a window and about 10 ft. distant therefrom, was at no time sufficient to soften the thin glass bulb of an incandescent electric light; and similar bulbs within 1 ft. of the window, but back a little behind the wall, were not injured.

Plate IX, Fig. 1, shows that in another room on the seventh floor, in which the plastering flaked off to a surprising degree, the heat was insufficient to melt the lead trap of the wash basin in the corner of the room, and that heat above the point of ignition of oak (?) only

continued long enough to consume about $\frac{1}{2}$ in. in depth of the chair Mr. Freeman. rail. The ornamental thin metal bulb of the lighting fixture in the center of the room does not show clearly in the photograph, but a careful inspection of its soldered or brazed joints would doubtless have given a tolerably accurate measure of the limit of the heat.

Plate IX, Fig. 2, affords much evidence of sound incandescent bulbs and uninjured plumbing; and the uncharred calendar hanging upon the farther wall shows that the heat in this room was mild in comparison with that which often occurs.

Plate VIII, Fig. 1, shows that the ornamental trimmings upon the electrolier, which were probably of thin spun brass, did not approach the point of fusion, and that small iron pipes were not softened enough to have become much bent. This photograph happens to present little detail, and gives much less information than could have been found by the sharp eyes of any good inspector in a ten-minute examination of the ruins; nevertheless, it causes the speaker to think it probable that the heat in this room was much less severe than in some of the fires in several small experimental buildings, constructed for testing the endurance of plaster on metal lath, which he has had occasion to witness at various times.

In one set of these experiments, common old-fashioned plastering of lime mortar tied together with hair was used, this being spread on wood lath in one and on wire lath in the other building. In another set of experiments, King's Windsor cement was used on metal lath, and in a third set, if memory serves aright, "adamant wall plaster" was used on both wire lath and expanded metal lath. In one set of these experiments the heat was sufficient to melt small tags of thin sheet brass, and in all of them the plastering on wire or metal lath showed a better resistance and endurance against fire than the plastering in the Methodist Building, as shown by this photograph. Whence, it may be inquired what kind of plastering this was, and to what was its weakness due? The speaker would suggest caution that the fire resistance of good plastering on metal lath be not underestimated from these photographs.

Figs. 1 and 2, Plate V, give some very interesting evidence on the behavior of naked cast-iron pillars exposed to very severe radiant heat, and doubtless also struck by hose streams while still hot. This piece of evidence is very suggestive, if taken in connection with the tests on naked cast-iron pillars made by the Committee on Fire Proofing Tests, acting on behalf of the Underwriters, the Architectural League and the American Society of Mechanical Engineers, at the Continental Iron Works, in New York City, about two years ago; and may possibly indicate that the committee having these tests in charge made their conditions more severe than commonly arise in practice. The photographs show the front of the Horne Office Building sup-

Mr. Freeman. reported by naked cast-iron pillars; yet the heat which chipped the Indiana limestone piers produced apparently no more effect on the pillars than upon the pressed-brick piers above them. Possibly, cooler air entering the building at this place may have aided in their preservation, just as the grate bars in a furnace are preserved. The showing made in this photograph, and in some larger photographs of these ruins which the speaker has seen, is so remarkable, that it is to be hoped that the author will give more particulars regarding these cast-iron pillars.

For about ten years the speaker has been studying the fire resistance of naked cast-iron pillars with much interest, and has come to believe that the character of the cast-iron pillar has been defamed to a much greater extent than is justifiable. The photographs shown on Plate V appear to be good evidence that, up to a higher limit than is commonly supposed, a cast-iron pillar will stand straight and carry its load. From day to day the speaker had carefully examined the naked cast-iron pillars removed from the ruins of the Ames Building, Summer Street, Boston, burned on Thanksgiving Day, 1889, and found that a majority of them were good enough to be used again. In this fire the area burned over, and the amount of combustible was probably not very different from that at the Horne store. The cast-iron pillars from the ruins of one of the Fall River Cotton Mills, which had its roof and upper story burned off some fifteen years ago, were actually used over again; and at a mill which the speaker had inspected in England in 1889, immediately after a fire which burned off the roof, and which was so hot that it softened 2-in. shafting until it hung in festoons, he found nine-tenths of the naked cast-iron pillars apparently good enough to use again. In the experiments made by Luehmann and Maeller in Hamburg in 1888, and in the admirable series of tests begun at the Continental Iron Works in Brooklyn two years ago, the naked cast-iron pillars, although heated to dull redness, did not crack or shatter when dashed with water. These tests were few in number, but the same results were indicated by such evidence as the speaker had gathered from actual conflagrations; and are not these pillars in the Horne Office Building another instance? Or, were the pillars out of reach of the firemen until the severe heat was past?

Another point well brought out by Fig. 2, Plate VII, in connection with Fig. 1, page 123, is the excellent power of resistance of an ordinary brick partition wall, like that which separated Hall Brothers building from the total ruin on their left. It would be interesting to know how hot the off-side of this party-wall became and how thick it was.

Coming to the main point of the paper and the question, "Can buildings be made fire-proof?" the speaker thinks that, approaching

the subject from a different side and speaking broadly, it may be said that they can. The way that he would approach the subject would be by saying that buildings like these can be made practically fire-proof and their contents very well protected at an expense not exceeding 2½ or 3 cents per square foot of floor, and the means which he would recommend for accomplishing this would be, not by increasing the thickness of the terra cotta, but by putting in automatic sprinklers. Mr. Freeman.

The speaker has studied the matter of automatic sprinklers very carefully for the past twelve years. Their general introduction into factories first took place under the auspices of, and with the encouragement of, certain fire insurance companies with which he has long been connected as Engineer; and so, for a long time, he has had occasion to follow carefully their results in extinguishing and checking the spread of fires. From this experience, and from having held inquests on a great many fires, he has no hesitation in saying, that in a building situated as was the Methodist Building, the interior loss would have been small, and confined mainly to water damage, if it had been protected by automatic sprinklers. In the case of the Horne Store Building, he believed that a thoroughly well-designed system of automatic sprinklers could have saved it, or, going back a step farther, there are nine chances out of ten that an equipment of sprinklers would have saved the Jenkins Grocery Store. The only doubt concerning the efficiency of sprinklers for saving the Horne Store Building is that the area of each of the front windows is perhaps 25% greater than that of the windows in buildings similarly situated where sprinklers have done most excellent service, and have prevented the fire from penetrating more than 20 ft. into the building.

This excess of window area need not be an insuperable obstacle, for probably by the use of iron sash with wire-glass for the upper third of the window, a great increase of fire resistance could be secured with no sacrifice of illuminating properties. Indeed, if this wire-glass be properly corrugated, the light will be better diffused. The lower part of the window might be of ordinary plate or blown glass as usual. These sprinklers, dotted all over the ceiling, 10 ft. apart, would preferably and naturally have their feed pipe branches perpendicular to the face of the building. Probably only two, or at most three, rows of heads nearest the exposed windows would have been opened. The number thus simultaneously in play would not be greater than any well-arranged water pipe system would supply, and the distribution of this water in the form of a rain of jets and drops, more copious than the heaviest shower, would drench nearly all the inflammable stock beyond the point of ignition. The water thus applied would be far more evenly distributed than from a nozzle in the hands

Mr. Freeman. of the best of firemen. Sprinklers are in truth very economical in their use of water. From what the speaker had seen of their work elsewhere, he believed they could at least have made it possible for the firemen to freely enter both of the Horne Buildings and prevent their destruction.

As an illustration of the comparative cost of protecting by automatic sprinklers and by fire-proof construction, the speaker cites the case of one of the most noted machine shops in America, that of Brown & Sharp, in Providence. Mr. Sharp wanted a building where his business would be safe against interruption by fire. He built it with cast-iron pillars, brick arches and a plank floor on top of the arches. Such construction was more expensive then than now, and the building is said to have cost somewhere between \$2.00 and \$3.00 per square foot of floor. If the building had been of standard plank and timber floor construction, extra heavy, costing \$1.00 per square foot of floor area, for the entire structure, and had then been supplied with automatic sprinklers, costing an additional $2\frac{1}{2}$ or 3 cents per square foot of floor, the result would have been even greater safety against interruption to business by fire, and a structure more proof against fire than that with iron pillars and brick arches, but without sprinklers. In other words, 3 cents worth of sprinklers would have given fully as much fire protection as \$1.50 worth of brick arches and iron beams. In this particular case, however, the brick arches should be credited with an additional value, as they afforded a stiffer floor for fine machinery. The speaker makes this statement of comparative safety deliberately, after having followed the records of fires under sprinklers quite carefully, both in England and in America, and after having talked over the history of factory buildings and of fire-proof material in Lancashire, England, at much length with some of their most expert firemen and experienced fire underwriters. The insurance records and rates, based not on isolated examples, but on very many buildings, show that the American type of mill construction with its plank and timber floors, wooden pillars and automatic sprinklers, is as safe against fire as the type of cotton factory building, common in Lancashire for the last fifteen years, and which has cast-iron pillars and brick floor and ceiling arches, but no sprinklers.

As illustrating the economy of making buildings fire-proof by automatic sprinklers, the speaker roughly estimates that the Horne Store Building could be thus protected at a cost of about \$2 500. It is stated that the value of the building and contents was about \$357 000, so that less than 1% of the value would have made it very nearly fire-proof, and the loss in that case would have been mainly water damage and the renewal of windows—only a fraction of the actual damage. The fire insurance companies, with which the speaker was connected as engineer for about ten years, have on record

instances of buildings where sprinklers have most admirably pre- Mr. Freeman.
vented fires from extending across narrower spaces than that between
the Horne and Jenkins buildings.

Lest it be thought impracticable to make a building with large
floor areas fire-proof, it may be said that in the insurance companies
with which the speaker is connected, risks have to be taken on areas
five times as large as those mentioned by the author. For instance,
some mills, like the Ponemah at Taftville, Conn., four or five stories
high, have floors 100 ft. wide and 700 ft. long, without partitions from
end to end, and in the carding room a large amount of cotton, cer-
tainly quite a combustible substance, is exposed. The number of
such very large rooms is too small to give a fair average experience,
but no fire has yet started in a large room having sprinklers, with an
ample water supply, which has not been brought under control or
held by them, so that men with hose streams could readily control it.
In fact, the speaker can say, after watching for ten years the fire
records in perhaps 2 000 factories protected by automatic sprinklers,
that a case has never occurred where such sprinklers, supplied under
a static pressure of say 30 lbs., and through pipes laid out on a
reasonably good scale, have ever failed to hold the fire in check so
that the firemen could very readily take care of and extinguish it. The
only cases which can be classed as doubtful are those where the fire
was at first shielded from the action of sprinklers and gained such
headway before breaking forth as to open more sprinklers than the
available water could supply.

The discussion of automatic sprinklers appears to come here fairly
as an answer to the title of the paper. In buildings, so high as to be
beyond the reach of the ordinary appliances of the fire department,
with large floor areas and with contents of a combustible nature, the
speaker believes automatic sprinklers to be almost the only adequate
protection obtainable.

When a sprinkler system is installed in a building where the street
mains do not afford sufficient pressure, a supply of water may best be
stored permanently on the roof. The tank in such cases, should be
as large as possible, and should have a capacity of at least 10 000
galls., and the sprinkler system should have ample steamer concentra-
tions at the sidewalk level. A 10 000-gall. tank may, under severe cir-
cumstances, be emptied in ten minutes, if 50 sprinklers happen to
open at once, and the speaker would consider such a system, fed from
a tank, worth only about half as much as one fed by a 6-in. or 8-in.
pipe under 75 lbs. pressure.

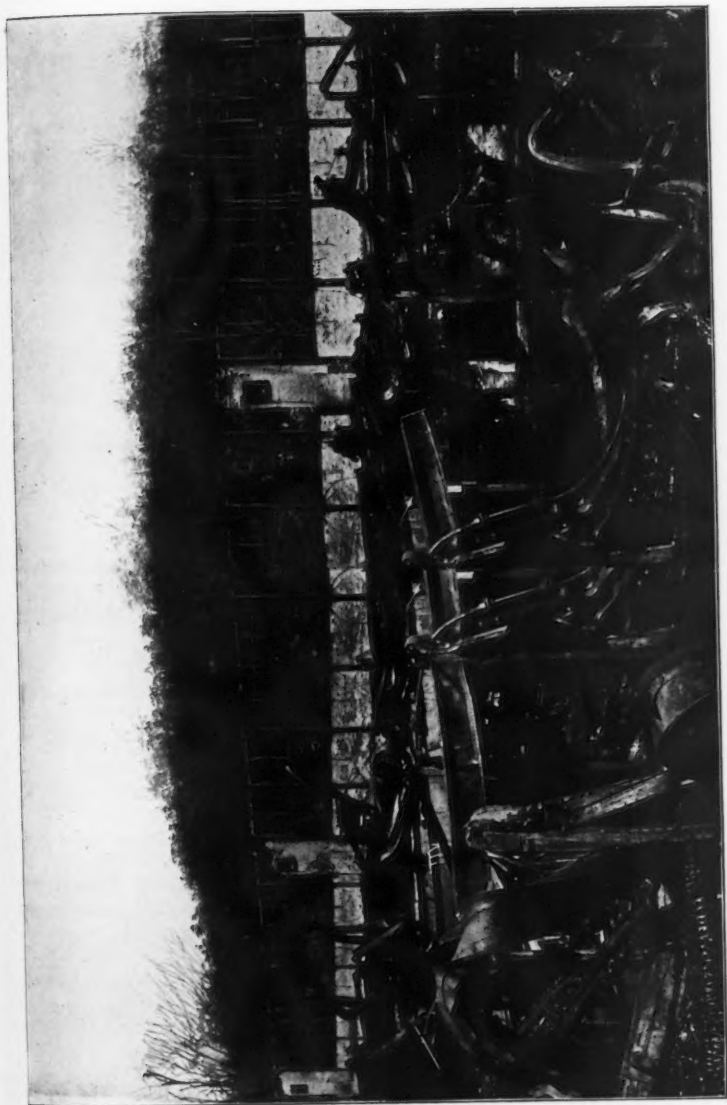
In reference to proportioning the sizes of pipes supplying sprink-
lers, the speaker thinks that the schedule of sizes in most common
use is not quite adequate for the number of sprinklers necessary to
cope with a widely spread fire on the upper floors of a building as

Mr. Freeman. large as the Horne Store Building; but it is very easy, by the ordinary rules of hydraulics, to proportion the sprinkler system so that it will take care of any ordinary or even extraordinary fire, and hold it from spreading, give the firemen time to extinguish the stray sparks at their leisure, and still keep the cost in a large job under 2½ or 3 cents per square foot of floor.

As to the use of wire-glass to help make buildings fire-proof, the speaker strongly endorses the remarks of Mr. Constable, having himself experimented upon it and made use of a considerable quantity in skylights and partitions. He has not had opportunity to examine any that had gone through a bad fire, but his tests of small sheets and some tests on large sheets made in Philadelphia gave excellent grounds for relying upon it. That which the writer used for skylights about four years ago had cracked somewhat under the action of sun, heat and cold, possibly because the sheets were too large, but since that time the process of manufacture is said to have been so much improved that this cracking does not occur. In the Horne Store Building wire glass might not only have been very useful for the upper third of the very large window areas, but also for forming a curtain or pocket 3 or 4 ft. deep around the open central well just under the ends of each floor, by which the passing of heat and flame from story to story would have been retarded. This would also have prevented the unnecessary opening of automatic sprinklers (had there been any) in floors above the seat of the fire. Within the past few months the speaker has used this wire-glass, set in cast-iron window frames, for certain small storehouse windows, with great advantage, in a situation where fire shutters would be difficult to maintain.

In reference to the use of fire shutters, the speaker recalls many instances where their value as fire-retarders has been shown. In the great fire in Lynn, Mass., some eight or nine years ago, he happened to have the good fortune to be in the city, and followed the fire from point to point. A very instructive example of the value of shutters was observed in the case of a shoe factory, close to the burned district, and separated from a two or three-story wooden building only by an alley perhaps 15 ft. wide. The windows were protected by shutters about 1½ ins. thick, covered on both sides with tin, and the heat was so great that much of the tin was melted from the outside of the iron plates. The wood of the shutters, as found by a subsequent examination, was charred in perhaps ¾ in. The shutters were warped in some cases 1 or 2 ins.; but the point of chief interest, as demonstrated by that fire, was that tin-clad shutters prevented the passing of heat to such an extent that men could work behind them and stand close to the windows with pails and tin dippers, and whenever a window sash caught fire could put it out. The men who fought the fire in that factory said that if the shutters had been iron they doubted

PLATE X.
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FREEMAN ON FIRE-PROOF CONSTRUCTION.





if they could have stood there, and, from experiments which the Mr. Freeman speaker has made on iron shutters, he also doubts it, as under such a heat the iron sometimes gets red-hot and crawls, twists and curls badly—opening wide cracks at the edges.

With the tin-clad wooden shutter, just as with the cast-iron pillar, there is a limit beyond which it cannot be relied on to serve, and that limit is not reached in perhaps one fire out of ten. The speaker has had good opportunities to study the matter during the past ten years. In the so-called Peabody-Whitney fire, in Boston, there was a mass of flame, probably greater than that in the Pittsburg fire, playing right against windows distant only across an alley-way about 15 ft. wide, and there the limit of endurance of tin-clad shutters was passed.

It has been the speaker's intention to complete some experiments on fire shutters commenced about a year ago, but never finished for want of a suitable building on which to test them. He had begun by having about twenty shutters made in different ways, and had tried some comparative tests by simply hanging a shutter of the ordinary size over the big flanging fire in the center of a large boiler shop. Each shutter was hung the same distance from the floor, and the blaze was regulated so that, as far as possible, judging by the eye, the same degree of heat was obtained. So far as these tests went they showed that there is nothing better than the ordinary type of tin-clad wooden shutter, but they also indicated that the ordinary nails are not long enough, and that lock-jointing the edges of the tin is not necessary if the nails are long. The heat runs in along the nails and chars the wood around them to a depth of about $\frac{3}{4}$ in., so that if $\frac{3}{4}$ -in. or 1-in. nails have been used, there is not much left beyond the heated portion for the sound wood to grip. Without doubt, the limit of endurance of fire-doors can be very much increased by using long nails.

For subdivided areas, where a door in a fire wall is needed, the speaker has for some time past recommended that two fire-doors be put in; one to take the brunt of the battle, and the other to hold back the stray streaks of flame which would get through after the first door had warped or begun to yield.

Plate X is from a photograph of the ruins of a very interesting fire which occurred at Worcester, Mass., a year ago, and shows that naked steel framing girders of ordinary **I**-beams or built-up columns have not a fraction of the endurance of cast iron and wood. The fire occurred in the spring shop of the Washburn & Moen Manufacturing Company, a building where they coil wire springs. Much of the work was heavy, such as large springs of $\frac{1}{4}$ -in. wire for the Westinghouse air brake and other work of that nature. The building had very large window areas and had a steel frame composed of built-up steel columns of channel bars with diagonal latticed work on the sides uniting them. All the girders were built up, and the building was

Mr. Freeman. only two stories high. The only woodwork about it was the floor and the roof. That building was considered by Mr. Moen so extremely safe that it was absolutely absurd to consider having sprinklers in it. It should be mentioned, however, that the floor was somewhat oily, due to the oil which had spattered out from the tanks in which the springs were tempered; but at the time of the fire, which occurred on Sunday afternoon, this oil had all been withdrawn from the tanks, and the only oil in the building was that which had soaked into this wooden floor.

The floor was of 3-in. plank; the roof of 2-in. plank, and some light rafters, perhaps 8 ins. x 12 ins., supported the roof. The fire commenced at about five or six o'clock in the afternoon, and in about 15 or 20 minutes "everything slumped," as an observer described it. The fire had evidently, at that time, reached the critical point mentioned by Mr. Constable, somewhere about 700 or 800° Fahr. It is interesting to observe the tangled mass of ruins. Some of the wooden rafters were only burned in about $\frac{3}{4}$ in. on the face, by a fire which completely wrecked the building and dumped everything into the cellar. The wreckage was absolutely without value, as it cost more to remove it than the scrap was worth.

Perhaps one reason why ordinary brick-work stands fire so well is that the units are so small, and just as the man who builds a Portland cement sidewalk cuts it up into squares of moderate size to prevent strains and cracks, and just as Mr. Hermann Schussler in building the San Mateo Dam of concrete, made it in blocks of limited size so as to have some "give" between the units, just in the same way the small size of ordinary brick as compared with the regular terra cotta blocks may present a reason why the bricks stand so much better.

CORRESPONDENCE.

Mr. Kaufman
and
Mr. Swensson.

GUSTAVE KAUFMAN and EMIL SWENSSON, Members Am. Soc. C. E.—Owing to the failure of the author so to do, the writers take the liberty to state that they, in connection with F. L. Garlinghouse, C. E., formed the Board of Engineers, referred to in the paper, that reported on the effects of the Pittsburg fire to the Board of Insurance Adjusters.

The narrative of the fire as given by the author is correct, as is also the statement of the effects of the fire on the structure, and the writers would have no comments to make were it not for the adverse criticism made upon their conclusions, and for several statements of the author, for which there would appear to be but slight or erroneous reasons. One of these is that the cinder concrete forming the filling above the floor arches was entirely decomposed by the heat. The writers would

like to know how the author arrived at this conclusion. It is a well-known fact that much so-called concrete is no concrete at all, but in the opinion of the writers, it is a very rash assertion to make, that this concrete was destroyed by the heat, in the absence of proof as to the condition of the filling before the fire. In certain spots on the first floor, where the wooden flooring boards were not burned, the filling underneath was in the same decomposed condition as the other concrete filling throughout the building, and, in the opinion of the writers, it is doubtful whether this concrete filling ever had set.

The writers would also like to ask the author what evidence he has upon which to base the statement that the deflection of the concrete floor arches in the Methodist Building has been increased by the fire? Did he have a measurement of the amount of the deflection before and after the fire?

In regard to the statement of the author, "that the fire teaches nothing as to the real fire-proof qualities of good concrete in floor construction, because the floors in the Methodist Building were not subjected to a real test. The heat on the outside of this building was only a fraction of what it was on the other buildings, as testified to by the firemen and by the fact that the stone trimmings in the exterior walls were only slightly injured."

It is presumed that the testimony of the firemen was taken by the author, as the writers have no knowledge of such being otherwise taken. Verbal opinions are not testimony. The stone trimmings of this building are of Beaver Valley sandstone, a stone which has fire-resisting qualities equal almost to that of fire-brick, while the Indiana limestone used on the other buildings is notoriously poor in resisting fire.

In the report of the writers to the insurance adjusters there was no statement made that this fire proved that concrete was a better fire-proof material than burnt clay; in fact, the writers were very careful to make no statements of that kind. They did, however, say, that the tests made by the building department of New York City proved that properly made concrete was as good if not better than burnt clay.

One of the most important features in the writer's report was entirely ignored by the author, namely, that there was a lateral motion of the whole building amounting to 2 ins. A careful study of the columns showed that there was considerable distortion within that limit. The Board of Engineers attributed to this fact the scaling off of the lower webs of the clay fire-proofing. It must be remembered that none of the floor arches above the second floor were exposed to streams of water. With these facts before it, the board made the statement that the fire-clay floor was unable to counteract the tendency to lateral motion. The author's statements that "a panel surrounded by iron will enlarge in area if the iron expands," and that "the pro-

Mr. Kaufman
and
Mr. Swensson.

Mr. Kaufman
and
Mr. Swensson.

cess of expansion would seem to relieve the arch in whole or in part instead of bringing any strain to bear upon it tending to its destruction," would be true did the panel retain a similar shape, but if there is distortion the arches will certainly give way. The careful instrumental examination made by the Board of Engineers should conclusively show that there was distortion sufficient to cause the lower webs to scale off. On account of the fire-proofing having been stripped from the columns, the writers also made the statement that the column protection was not of sufficient strength.

This building was only six stories high, and had it been fifteen stories high it would have been necessary to take the whole structure down, had the leaning been at the same proportion as developed in this fire. The writers, after a careful perusal of this paper, see, as yet, no reason to change their most important conclusion, which was as follows: That the fire-proofing material should in itself be strong, and be able to resist severe shocks, and should, if possible, be able to prevent the unequal expansion of the steel work and fire-proofing.

There seems to be but one material that is now known that could be utilized to accomplish these results, and that is first-class concrete. The fire-resisting qualities of properly made concrete have been amply proven to be equal to, if not better than, fire-clay tile, as shown by the series of tests carried on by the Building Department of the City of New York.

From the experience gained in street railway construction in laying continuous rails, it is shown to be to a large degree possible to prevent the metal from expanding. In street railway work this has been accomplished merely by the adhesion of the pavement to the sides of the rails. In building construction the same results could be obtained by encasing the columns and girders in concrete placed directly against the steel work. The adhesion of the concrete would to a large degree prevent unequal expansion of the concrete and steel. The construction herein suggested should not materially increase the cost of construction. The solid concrete about the columns would be added strength to the same, and could, no doubt, be made self-supporting. The same could be said of concrete surrounding beams and girders, as has been amply demonstrated by the strength developed by concrete iron constructions, such as the Monier and Melan arches.

One of the objections that would be raised against this construction would be that it could not be carried on in freezing weather. This is a proper objection, but, in the opinion of the writers, there is no valid reason why these structures should be built in winter any more than were the old-time brick structures.

MACE MOULTON, M. Am. Soc. C. E.—It is a matter of congratulation that the author should present at this time such an able paper on fire-proof construction, as there is certainly much need that all possible light should be thrown on this important subject, involving, as it does, the protection of human life and vast proprietary interests in all classes of important buildings and their valuable contents. It is certainly advantageous that the effects of the more recent large fires should be cited and discussed, as they describe several varieties of fire-proofing subjected to diverse conditions and showing much variation in the results of their trials.

The writer, however, should have been glad to have read something by the author regarding the value of, and his deductions from, the Denver tests, and the more recent ones in New York City, on the various systems of fire-proofing as applied to floors, and he trusts that the discussion will bring out some points observed during these tests which may help to a better comprehension of the facts which are shown by the remains of the so-called fire-proof buildings after the test of a hot fire.

In the published reports of the several large fires which have occurred during the last few years in buildings supposed to be fire-proof, the conclusions drawn from the observed facts appear to the student of this question to be diverse, and these conclusions are by men whose engineering judgment would generally be considered sufficiently good to command for them respectable fees when consulted. In a certain sense all are in the student grade in considering these matters, and are in such a condition that each conclusion drawn by another is examined to see if a true settlement of a certain question has been reached and a real step forward accomplished.

In regarding the paper in this spirit the writer is hardly able to agree with some of the author's deductions, while others seem to be the only true ones. It does not seem quite evident to the writer, from the author's report of his examination, or from any other information available regarding the condition of the concrete immediately under the wooden flooring of the Horne buildings, that the concrete was disintegrated by the fire or by the water.

The usual practice on tile floors, and, in fact, in most fire-proofing systems, is to put what is termed "filling" over the main arches, which filling is not supposed to contribute materially either to the strength of the arches or to the fire-proofing, except as it may fill up the spaces between the main sustaining arch or plate and the finished floor, thus preventing a free circulation of hot air or flame, and serving as a light-weight packing about the wooden sleepers to which the flooring is nailed. This filling, being somewhat a secondary matter, is frequently very weak when considered as concrete, but it is incombustible. Naturally, then, in case this practice was followed in

Mr. Moulton. making the floors of the Horne building, as seems probable, the appearance would not be that of well-made concrete, but might readily be as poor, when compared to good concrete, as reported by the author, and still be doing the duty for which it was put in, simply to fill space closely with an incombustible material. It therefore seems to the writer that the concrete over the tile arches was not seriously injured by the fire, but was practically in its original condition as put in.

The fire in the Methodist Building evidently was not hot enough to injure the concrete flooring, and the partitions in this building, with wooden studs, certainly could not have been put in with the intention to make them fire-proof, but probably the expanded metal lath was used with the expectation that it would hold the plaster longer in a fire than wooden lath, and thus give the partitions a certain value as a retarding element to the progress of the flames. In nearly all the large fires recently reported on, where plaster occurs in connection with fire-proof construction, there appears to be very little bond between the plaster and the surfaces to which it is applied. This would seem a fair field for improvement. Can plaster be made to stick well enough to withstand the alternate attacks of fire and water? It is generally admitted that lime mortar plaster is in itself a good fire resister, better in fact than hard plaster when subjected to water after heating. The question then would be to get it to stay on better, and thus the first stage of destruction would be retarded and the destroyer kept away from the skeleton longer.

The writer agrees with the author that flat ceilings are best, and he would go to the extent of stretching suspended ceilings under any system of flooring fire-proofing, which did not fill the space between the joists or beams, in order to get the best conditions; but would fire-proof all of that part of the beams projecting below the main arch or plate just as thoroughly as if no secondary ceiling was contemplated or used. In such cases this would act as an obstruction which, although it could not be expected to last long under the severe heat, or the assaults of the stream from the hose, might be depended upon to retard the heating up of the fire-proofing and also the metal skeleton, and leave the fire-proof material less likely to be broken out by the sudden contraction when water struck it than was the case at the Pittsburg and the Chicago Athletic Club fires quoted by the author.

In relation to the Athletic Club fire, the writer cannot see how the author can quote this, as an instance, to prove the statement that 4-in. porous hollow tile partitions will stand fire and water without material injury, if the published reports of that fire and the photographs of the condition of the partitions are to be believed. One report says that the firemen explained the absence of any great amount of debris of the destroyed portions of the partitions by observing that the heated tile

appeared to disintegrate into powder when the water struck it. This Mr. Moulton. was a case of porous hollow tile apparently well set, and it seemed to suffer worse than that in the Horne office building which was improperly set.

It appears to the writer that too much is being expected from 4-in. hollow walls thus made, and he believes that something thicker and more elaborate will have to be made if partitions are to be fire-resisting walls, as the force of the stream of water is in itself in some cases sufficient to knock out parts of them.

The writer is glad to note the disposition of different manufacturers of fire-proofing systems to do so much in the way of building samples for testing by experts, and it is to be hoped that exceedingly careful and intelligent records will always be made and wide publication given to them, so that workers and students in this field may have the opportunity to study them understandingly, and as far as possible profit by them in practice.

CORYDON T. PURDY, M. Am. Soc. C. E.—In resistance to the effects Mr. Purdy. of fire, cast-iron columns have an advantage over ordinary steel columns. They are in one piece, and, especially in the lighter sections, are not as thin as those of steel; but aside from this, it is probably true, as stated by Mr. Freeman, that cast-iron columns will resist fire better than built-up steel columns of the same strength. Nevertheless, in public estimation, the former are giving way to steel as desirable columns for large buildings, because cast iron is not as reliable, and will not admit of the use of rivets in connections, upon which the general stiffness of an iron frame largely depends. In special cases cast-iron shells over steel columns are very desirable as fire-proofing.

The author also agrees with Mr. Freeman regarding the excellent resistance of ordinary brick-work to fire. It would seem to have been demonstrated sufficiently that nothing is better.

From personal observation the author came to the conclusion that the cinder concrete over the floor arches in the Horne Buildings was entirely decomposed by the heat. Good cinder concrete has the reputation of enduring heat better than any other, and although he could not find out how this concrete was made, yet the fact that it had little or no coherence after the fire indicates that its character was poor.

The author is not prepared to prove that the deflection of the concrete floors in the Methodist building was increased by the fire. His statement in reference thereto is not a definite assertion; however, he thinks that reliable evidence to prove that it was thus increased can be obtained. If the fire cannot be blamed for the deflection afterward existing, that particular piece of floor-work is certainly open to severe criticism; for the deflection was more than twice as great as the maximum usually allowed, and was unpleasantly noticeable in the finish. If the fire did not increase the deflection or otherwise injure the con-

Mr. Purdy. crete, the question might also be asked, why did the owner, when the building was repaired, re-enforce with new beams the arches which had been exposed to the fire?

In order to get the best testimony regarding the heat of the fire, and an accurate story of its progress, the author interviewed the firemen and made memoranda of the facts as given by the chief having charge of the force. He has refrained from any extended criticism of the report made by Messrs. Kaufman, Swensson and Garlinghouse, because such reference was not necessary in bringing out the lessons of the fire, and did not seem to be appropriate. He does not coincide with them in their deductions. They practically, and in effect, argue that protection from heat is not the ultimate desideratum, and this, from his point of view, is the greatest mistake of all. On the other hand, he is in entire sympathy with Mr. Prichard's view of the matter. If beams can be protected so well that a temperature of $2\,000^{\circ}$ will not injure the paint on them, their expansion need cause no apprehension.